Investigation report

C2/2009L

Serious incident at Helsinki-Vantaa Airport due to tread separation and hydraulic failure, 22 June 2009

OH-LQE

Airbus A340

Onnettomuustutkintakeskus
Centralen för undersökning av olyckor
Accident Investigation Board

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SUMMARY

An incident occurred on the Finnair scheduled flight AY58 from Shanghai, China to Helsinki-Vantaa Airport, Finland on 22 June 2009. The aircraft was an Airbus A340-313, registration OH-LQE. There were 195 passengers and 12 crew members on board.

The inner rear tyre on the left landing gear separated and the tread rubber shredded during take-off at 02:17 (all times are in UTC). Rubber debris damaged hydraulic lines on the aircraft's landing gear and brake systems. The flight proceeded to Helsinki-Vantaa, landing at 11:53 without any further damage. No persons were injured in this incident.

The incident was classified as a serious incident. On 26 June 2009, Accident Investigation Board Finland appointed investigation commission C2/2009L to this occurrence. Investigator Vesa Kokkonen was named investigator-in-charge, accompanied by investigators Jouko Koskimies and Niina Aintila as members of the commission. Chief Fire Officer Heikki Harri was invited to assist the commission as a rescue service expert.

The takeoff was otherwise normal except for the fact that the Electronic Centralized Aircraft Monitor (ECAM) generated the amber caution BRAKES HOT. Approximately six minutes after takeoff the ECAM generated a caution related to a leak in one of the hydraulic systems (green). The crew acted according to the instructions displayed by the monitoring system. Four hours from takeoff the ECAM enunciated that the hydraulic fluid in the green hydraulic system had been depleted to the minimum level.

After the aircraft departed Shanghai, pieces of tyre with the marking *Finnair* were found on the runway. The pieces were delivered to the Lufthansa mechanic who performed the turnaround check on the aircraft. He then reported the matter to Finnair in Helsinki, photographed the pieces and e-mailed the photos to Helsinki. The photos indicated that the pieces came from OH-LQE's tyre number six, on the rear inner wheel of the left main landing gear. Preliminary information regarding a tyre failure was reported to the flight crew approximately three hours before landing. This was supplemented by precise information regarding the tyre in question 21 minutes prior to landing.

During the flight the crew assessed the problems caused by the hydraulic fault as well as the required corrective action. It became evident that, among other things, they had to extend the landing gear via gravity extension, which meant that the centreline gear would not extend and no nosewheel steering would be available. Later, the information of a tyre failure added to the uncertainty regarding the extent of the damage and the condition of the landing gear. Therefore, 40 minutes before landing, the captain decided that the cabin had to be prepared for a possible emergency during landing. The air traffic control at Helsinki-Vantaa arranged a priority approach and landing for the OH-LQE on runway 22L.The emergency response service was also alerted. The landing was successful but, during braking, the other hydraulic system (blue) began to leak through a fractured brake line coupling. After the aircraft had become stationary the blue system drained completely. Since nosewheel steering and brakes were inoperative the aircraft had to

stop and stay on the runway. After approximately 20 minutes the aircraft was towed to the apron, where the passengers deplaned.

Investigation revealed that tyre number 6 delaminated at takeoff and the tread shredded into pieces. Chunks of loose rubber flying off at high velocity damaged hydraulic lines on the green hydraulic system as well as the brake line coupling on wheel number 2. Wheel number 2 is in front of the damaged wheel number 6. The green system depleted to its minimum level through a rupture on the gear-up line. After the aircraft had come to a standstill, the blue system drained through the damaged brake line coupling.

The damaged tyre had previously been on another aircraft. The tyre had been sent for retreading because a pinhole had been discovered. The hole was not reported to the retreading company nor was it detected during the retreading process. Later, the tyre was installed on the OH-LQE. Pressurised air had been gradually seeping between the tread and the belt plies, causing the tread to begin to detach and finally separate at take-off in Shanghai. Rubber discoloration caused by overheating was detected during the inspection. It is possible that overheating degraded the integrity of the tread and the belt plies, thereby accelerating delamination.

The leaks on the green and blue systems were caused by the impact energy of the tyre shreds when they hit at high velocity the hydraulic lines in the wheel well as well as the brake line coupling on wheel number 2.

The investigation commission recommended that Airbus Industries evaluate the need for and possibilities of shielding hydraulic and electric systems in wheel wells.

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ABBREVIATIONS

ACARS	Aircraft Communication Addressing and Reporting System
bar	bar
BEA	Bureau Enquêtes Accidents
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DGR	Dangerous goods
EASA	European Aviation Safety Agency
ECAM	Electronic Centralised Aircraft Monitor
hPa	Hectopascal
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
JAR	Joint Aviation Requirements
L	Left
LT	Local Time
NCC	Network Control Center (Finnair)
psi	Pounds per square inch
QNH	Altimeter setting
QRH	Quick Reference Handbook
R	Right
RAT	Ram Air Turbine
TMA	Terminal Area
UTC	Co-ordinated Universal Time

SYNOPSIS

The incident occurred on Finnair's scheduled flight AY58 from Shanghai to Helsinki-Vantaa Airport on 22 June 2009. The aircraft was an Airbus A340-313, registration OH-LQE. There were 195 passengers and 12 crew members on board.

At takeoff the inner tyre on the main landing gear's rear wheel delaminated and the tread tore into pieces, damaging hydraulic lines on the landing gear system. In addition, one wheel's brake line was damaged either at takeoff or landing. The aircraft flew to Helsinki-Vantaa where it landed without any further damage. There were no injuries to persons.

The pilot-in-command filed an incident report as per the company's regulations. The persons in charge at the Air Traffic Control filed an incident report as per aviation regulations. The Area Control Centre reported the incident to Accident Investigation Board Finland (AIB).

The incident was classified as a serious incident. On 26 June 2009, Accident Investigation Board Finland appointed commission C2/2009L to investigate this occurrence. Investigator Vesa Kokkonen was named investigator-in-charge, accompanied by investigators Jouko Koskimies and Niina Aintila as members of the commission. Fire Officer Heikki Harri was invited as a rescue service expert to the commission. AIB Finland sent a notification to the European Aviation Safety Agency (EASA) as well as the French civil aviation accident investigation authority (BEA). Pursuant to ICAO Annex 13, BEA designated their accredited representative for the investigation.

All times in this investigation report are in UTC. The history of the flight was established through the aircraft's ACARS messages, DFDR and CVR recordings, ATC radiocommunications and telephone recordings, and by interviewing relevant parties. Experts at Bridgestone Aircraft Tyre (Europe), S.A., Airbus Industries and Finnair assisted in establishing the damage to the tyre and the aircraft's hydraulic systems. The investigation commission's expert established the action of the rescue service through interviews as well as from documents and recordings.

The draft final report was sent for statement and comments to the parties involved: the Finnish Civil Aviation Authority, Finavia Oyj, Finnair Oyj, the rescue service authorities, the Hospital District of Helsinki and Uusimaa as well as EASA, Bridgestone S.A., Airbus Industries and BEA. Finnish comments were received by 21.12.2009.

Comments from Airbus/BEA were received on 17.2.2010. The comments led to a teleconference on 18.2.2010 as well as subsequent correspondence. The investigators concur with the views expressed in the comments and they were used to enhance the investigation report. No other comments were received from abroad.

The investigation was completed on 27.4.2010.

The material used in the investigation is stored at Accident Investigation Board Finland.

1 FACTUAL INFORMATION

1.1 History of the flight

A serious incident occurred on 22 June 2009 at Helsinki-Vantaa Airport when a Finnair Airbus A340-313, registration OH-LQE, landed on runway 22L with a damaged tyre. In addition, one of the aircraft's three hydraulic systems was depleted to the minimum level and a second one drained after the aircraft came to a halt at the end of the landing roll. The aircraft was on a scheduled flight, returning from Shanghai. There were 195 passengers and 12 crew members on board.

The scheduled departure in Shanghai was at 01:40 UTC (09:40 Finnish time). Meteorological conditions were good. The relief pilot conducted the pre-flight external inspection and did not notice anything out of the ordinary. Lufthansa provides technical services for Finnair in Shanghai and the Lufthansa mechanic who dispatched the OH-LQE did not notice anything special during his turnaround inspection either.

Traffic caused a delay in departure. Engines were started at 02:01, followed by taxiing. The flight crew did not notice anything special during engine start or taxiing. Taxiing took 16 minutes and, due to traffic congestion in the morning, they had to stop several times. The ambient temperature was high: +32 degrees Celsius. According to the Digital Flight Data Recorder (DFDR), taxiing speeds were normal and the flight crew said that they did not have to brake hard at any time.

Takeoff occurred at 02:17 from runway 17L. The takeoff was otherwise normal except for the fact that they received an amber caution BRAKES HOT. This caution is displayed when brake temperature reaches or exceeds 300 degrees. As per the pilots' interview, the caution came from one of the rear wheels on the left main landing gear. The pilots said that, when airborne, the hottest brake reached a maximum of 290 degrees. Takeoff was not aborted because the Aircraft Operating Manual does not call for an abort in this situation. Due to the caution the landing gear was left extended longer than normal so as to cool the hot brake. Transition to clean configuration proceeded normally. According to DFDR information, both the green and blue system retained the normal 3000 psi (206 bar) pressure.

The aircraft has three hydraulic systems: green, blue and yellow. At 02:23 the Electronic Centralized Aircraft Monitor (ECAM) annunciated a leak in the green hydraulic system. The Aircraft Communication Addressing and Reporting System (ACARS) relayed the same information to Finnair's Network Control Center (NCC) in Helsinki. This information can only be annunciated after the aircraft has reached 1500 ft. According to the DFDR the aircraft reached this altitude at 02:18. After landing a leak was also detected in the blue hydraulic system

The green system is the main hydraulic system. The others are the blue and the yellow systems. After the leak annunciated, in accordance with ECAM instructions, the crew kept monitoring the fuel quantity of the green reservoir. The flight crew noticed that the green system reservoir level kept decreasing and, therefore, at 02:54 they turned off the

green hydraulic system pumps on engines 1 and 4 at which time they received a hydraulic low pressure caution for the green system. At 06:39 they received a reservoir level caution on the green system. At this time, in accordance with ECAM instructions, the electric pump on the green system was turned off. The electric pump is normally on standby and turns on only if an engine fails. This is why it had not started after the take-off.

During the flight the crew went through the hydraulic failure checklist and assessed what additional faults they might encounter during landing. They continually exchanged information with the NCC via the ACARS. It was noted that a green system failure necessitated a landing gear gravity extension. In such instances, the center gear does not extend and landing gear doors remain open. In addition, nosewheel steering, reverse thrust on the outer engines and two of the six spoilers remain inoperative. This translates into a 15% longer landing roll. Furthermore, the autobrake system is not available. Normally the green system provides hydraulic pressure for the brakes, but if it fails the aircraft automatically assigns braking to the blue system. The flight crew checked the aircraft's documents and noticed that fluid had been repeatedly added to the green system. In their opinion, this indicated a leak. Their anxiety only increased when Finnair Technical Services asked whether the log entries showed that the hydraulic system had been refilled. Only when the aircraft was repaired after the incident was it noticed that the green system had actually been leaking through an incorrectly tightened T-union in the spoiler system. In spite of log entries regarding hydraulic fuel having been topped up or hydraulic fluid residue found on the left landing gear's shock strut, the aforementioned leak had not been localised.

After the aircraft departed Shanghai pieces of tread were found on the runway. They contained the markings *Bridgestone* and *Finnair*. Because of this, the pieces were delivered to the Lufthansa mechanic. He photographed them and reported the matter to Finnair NCC in Helsinki who, in turn, relayed the findings to the flight crew at 08:54. When the photographs arrived in Helsinki by e-mail, tyre markings identified them as coming from the OH-LQE. At 11:09 this was finally confirmed to the flight crew. Twenty-one minutes before landing Finnair Technical Services informed the flight crew that the pieces came from tyre number 6. Throughout the flight all tyre pressure indicators on the flight deck indicated normal pressure.

When the flight crew got word of the tyre damage they gave consideration to its possible cause as well as to any other additional damage that may have occurred in the wheel well. They had no means of checking the damage, nor if any other tyres were also damaged. They decided that there were just too many unknown factors involved and that they could not be certain how the aircraft would handle during landing. Therefore, at 11:12, the captain decided to prepare the cabin for an emergency. The head of the cabin crew said that the passengers were prepared for this without any problems. Particular attention was given to advising mothers travelling with small children. Since the aircraft was almost booked to capacity, they could not shift passengers within the cabin. The captain gave the command "Brace for impact" at 11:52, i.e. approximately two minutes before landing. The passengers remained in the brace position for three minutes or so. There was no noticeable alarm among the passengers.

At approximately 08:00 Finnair NCC alerted the supervisor of Helsinki-Vantaa Air Traffic Control (ATC) of a hydraulic fault on the OH-LQE. The supervisor sent a preliminary alert to the Area Control Centre (ACC) as well as to the Tower Control (TWR), aerodrome apron and the Airport Rescue Centre at Helsinki-Vantaa. The ACC reported the situation to AIB Finland. The airport rescue centre on-call fire officer reported the situation to the on-call chief fire officer at Keski-Uusimaa Department for Rescue Services. Airport rescue response readiness was raised. At the same time the supervisor agreed with the rescue services that all subsequent measures were to be implemented as per standing instructions. The full emergency alarm was given at 11:22 at which time official emergency procedures were put into action. When the aircraft landed there were 13 rescue units and three police units on the movement area. The airport adjusted its traffic arrangements in such a manner that the OH-LQE could approach and land on runway 22L without delay.

The aircraft flew from Shanghai to Finland over the Russian Federation, arriving in Finnish airspace 45 minutes before landing via reporting point Agamo at FL 380 (11100 m), northeast of the city of Joensuu. When the aircraft contacted Tampere ACC at 11:09, it was cleared directly to VOR/DME Orima. A moment later the aircraft was recleared to FL 100 (3100 m) and then on to reporting point Vasuk. At 11:44 Helsinki Approach (APP) cleared the aircraft for an ILS approach on runway 22L.

The approach and landing proceeded without problems. The aircraft landed at 11:54 UTC (14:54 local time). The flight crew extended the landing gear approximately 10 minutes before touchdown. At first, with the consent of Finnair Technical Services, they tried to extend the landing gear in the normal fashion. However, when no hydraulic pressure was generated in the green system, they used the gravity extension system at 11:43. This is an electric/gravity powered procedure. The system worked properly. On the ground the aircraft decelerated almost as normal and the landing roll was not noticeably longer than usual. As the aircraft came to a stop, the hydraulic leak in the blue system, through the damaged brake line coupling on wheel number 2, was also discovered. Within four minutes of landing the blue system drained dry at which time the parking brake also became inoperative. The brake line coupling sprayed hydraulic fluid onto the hot brake causing it to vaporise, thereby creating a possible risk of fire. Fire fighters used air fans to cool the brake and then removed the hydraulic fluid off of the surface of the runway. After the landing a fairly large piece of tread rubber was found on the axis of wheel number 1 (front left wheel, left main landing gear). Also, small tyre pieces, none exceeding 10 cm in length, were found on the runway. Airport maintenance swept them away.

Since nosewheel steering was inoperative, the aircraft remained on the runway. Finnair Technical Services conducted a preliminary inspection of the damage to the aircraft and, approximately 20 minutes later, the aircraft was towed to apron where the passengers were allowed to deplane. The flight crew was immediately debriefed at the aircraft and, later, at the crew centre.

1.2 Injuries to persons

There were no injuries to persons.

1.3 Damage to aircraft

The tread on tyre number 6 on the left main landing gear shredded during takeoff. Nevertheless, the tyre kept its pressure during the entire flight. A small pinhole was found on the tyre's casing during the post-landing inspection. Nitrogen, used to pressurise the tyre, leaked through the hole.

Tread pieces had impacted the green system's hydraulic lines in the wheel well, causing an approximately 10 mm rupture on one line and a dent on the other. During the flight, the green system depleted to the minimum level in approximately 4 hours. Tread pieces also hit the brake line coupling of tyre number 2, right in front of the damaged tyre. The coupling broke, causing a hydraulic leak as braking was commenced. The investigation could not establish whether the coupling broke at takeoff or at landing. After the aircraft came to a standstill, the blue system drained onto the landing gear and the runway.

Figure 1.Hydraulic fluid on the runway

Other damaged parts also included:

- The inner left flap which sustained structural damage;
- Electrical wiring shrouds and fittings in the wheel well;
- The landing gear door gasket, including its fittings;

- The electronic control box door in the wheel well area; and
- Hydraulic line guides.

In addition, tread pieces left imprints or caused minor damage from the forward fuselage to the horizontal stabiliser.

Damage and fault inspection as well as repair were conducted from 22.6.–5.7.2009. Replacing the damaged electrical wire shrouds was the most time-consuming process. As structures were taken apart, the cause for the earlier detected depletion of hydraulic fluid in the green system was found. The leak was caused by an incorrectly tightened T-union on the spoiler system.

1.4 Other damage

There was no other damage.

1.5 Personnel information

Pilot-in-command: Age 48

Licences: Air Transport Pilot's Licence, valid until 22.6.2011.

Medical certificate: JAR class 1, valid until 12.5.2010 and JAR class 2, valid until 12.5.2011.

Ratings: All required ratings were valid.

Flying experience	Last 24 hours	Last 30 days	Last 90 days	Total hours
All types	10 h 25 min	56 h 45 min	155 h 16 min	12316 h 08 min
Type in question	10 h 25 min	56 h 45 min		

Co-pilot: Age 36

Licences: Air Transport Pilot's Licence, valid until 25.5.2014.

Medical certificate: JAR class 1, valid until 3.6.2010 and JAR class 2, valid until 3.6.2014.

Ratings: All required ratings were valid.

Flying experience	Last 24 hours	Last 30 days	Last 90 days	Total hours
All types	10 h 25 min	39 h 16 min	116 h 17 min	4363 h 25 min
Type in question	10 h 25 min	39 h 16 min		

Relief pilot: Age 40

Licences: Air Transport Pilot's Licence, valid until 17.9.2012.

Medical certificate: JAR class 1, valid until 25.6.2010 and JAR class 2, valid until 25.6.2011.

Ratings: All required ratings were valid.

Flying experience	Last 24 hours	Last 30 days	Last 90 days	Total hours
All types	10 h 25 min	19 h 19 min	148 h 07 min	3664 h 15 min
Type in question	10 h 25 min	19 h 19 min		

1.6 Aircraft information

Type:	Airbus A340-313
Registration and number	OH-LQE, 2052
Airworthiness certificate	Valid until 1.8.2009
Serial number and year of manufacture	Airbus 0938, 2008
Maximum takeoff weight	275 000 kg
Takeoff weight on the incident flight	239 706 kg
Fuel - at takeoff - at landing	 72 300 kg 6 880 kg
Owner	Finnair Aircraft Finance Ltd
Operator	Finnair Oyj

1.7 Meteorological information

Takeoff in Shanghai at 02:17 UTC

METAR 02:00 Wind 230 degrees 8 m/s (15 kt), visibility 7 km, temperature 32°C, dew point 23°C, QNH 999 hPa, no significant change (NOSIG)

Landing in Helsinki-Vantaa at 11:54 UTC

METAR 11:50 Wind variable 6 kt, visibility over 10 km, cloud base above 1500 m (5000 ft), temperature 20°C, dew point 6°C, QNH 1027 hPa, NOSIG

The weather enroute was very turbulent which was why the fasten seat belt sign was repeatedly turned on.

Meteorological conditions had no effect on the incident.

1.8 Aids to navigation and radars

All onboard navigation equipment and radar operated normally and did not generate any fault alarms.

The radar systems at Tampere ACC, Helsinki APP and Helsinki TWR operated normally. The navigation equipment and approach systems at Helsinki-Vantaa airport operated normally and did not generate any fault alarms.

The navigation and radar systems at Shanghai airport generated no fault alarms.

1.9. Communications

The aircraft's radiocommunications and the ACARS system operated normally. The ACARS transmitted 16 fault alarms from the aircraft during the flight.

Radiocommunications and telephone systems at Tampere ACC and Helsinki-Vantaa ATC operated normally.

Radiocommunications and telephone systems at Shanghai airport generated no fault alarms.

1.10 Aerodrome and Air Traffic Control information

1.10.1 Aerodromes

Shanghai Pudong International Airport ZSPD was the point of departure. The aerodrome chart as well as the taxiing route of the OH-LQE is shown in Appendix 1. The aircraft took off from runway 17L.

Helsinki-Vantaa International Airport EFHK was the point of landing. The aerodrome chart as well as the landing track of the OH-LQE is shown in Appendix 2. The aircraft landed on runway 22L.

1.10.2 ATC action at Helsinki-Vantaa

Finnair NCC reported the OH-LQE's hydraulic fault to Helsinki-Vantaa ATC at around 08:00. In order to prepare for the situation the shift supervisor requested the NCC to ask the flight crew the following questions:

- Could the OH-LQE vacate the runway on its own;
- Would they make the approach at a higher or lower airspeed compared to normal; and
- Would they dump fuel in EFHK airspace?

Earlier, at around 09:00, Finnair NCC had confirmed the number or persons aboard, the estimated fuel quantity at landing as well as the fact that the aircraft did not carry any dangerous goods (DGR). In his answer the captain thought that they could vacate the runway. However, he added that they would probably require towing assistance and that they would use a lower airspeed compared to normal during the approach. He estimated

that the landing roll would be approximately 20% longer than normal. There was no need to dump fuel.

The supervisor then planned the use of runways on the basis of this information. Runway 22L was reserved exclusively for the OH-LQE. As early as 11:10 the supervisor knew of the tyre damage in Shanghai. Therefore, the aerodrome emergency plan also included runway sweeping and a post-landing inspection. Approximately 13 minutes before landing the captain responded to the ATC's query by saying that they could not vacate the runway on their own. Instead, they would remain on the runway. At this point the ATC decided to alter the plan by using only runway 22R for other traffic. Nonetheless, after a rapid assessment of the traffic situation, the supervisor decided to implement the so-called Open-V procedure, which entailed reserving runway 22R for takeoffs and runway 15 for landings. Tallinn ATC was advised of possible delays due to the fact that only one runway was available for landing for aircraft approaching through the Tallinn area. Three runway sweeper vehicles were earmarked to sweep the intersection of runway 15 and runway 22L as well as the length of runway 22L. This was subsequently implemented so effectively that there was no delay to approaching aircraft in the Terminal Control Area (TMA). Later, the use of only one runway caused an approximately one hour delay to other traffic.

The Air Traffic Control operated in accordance with the aerodrome emergency plan. The ATC supervisor was in charge of the situation, assisted by a coordinator at the TWR. Uncertainty was caused by the fact that the ATC was not fully aware of the consequences of the hydraulic fault, or the extent of the damage on the left landing gear. Therefore, they did not know how long runway 22L would have to be reserved for the OH-LQE. The emergency situation was finally called off at 12:30.

1.11 Flight recorders

Digital Flight Data Recorder (DFDR):

Type	Honeywell SSFDR
Part number	980-4700-042
Serial number	SSFDR-14422
Recording capacity	25 hours

The DFDR clock turns on when the first engine is started. It counts the time from engine start in seconds. The recording also stores the time in UTC. The DFDR was removed from the aircraft at Helsinki-Vantaa after the flight. Finnair downloaded the recording which was analysed at AIB Finland.

Cockpit Voice Recorder (CVR):

Type	Honeywell SSCVR
Part number	980-6022-001
Serial number	CVR 120-11850
Recording capacity	2 hours (120 minutes)

The CVR recording was downloaded by Finnair and analysed at AIB Finland.

1.12 Runway and aircraft inspection

Finnair Technical Services inspected the aircraft immediately after landing, before it was towed off the runway. The damage was recorded and photographed. Airport maintenance inspected the runway and swept off the tread pieces that came loose during the landing. Hydraulic fluid that leaked on the runway was removed.

Pieces of tread were found in Shanghai during a runway inspection. It is not known exactly where they were located.

1.13 Medical and toxicological information

No medical or toxicological tests were conducted.

1.14 Fire

There was no fire. The aircraft had approximately 6 900 kg of fuel at landing. Left main landing gear brake temperatures were high and there was a risk of fire. The broken brake line coupling on wheel number 2 sprayed hydraulic fluid onto the hot brakes and the fluid vaporised. The fire units cooled the left landing gear with air fans and Finnair's technical inspector released pressure from the damaged tyre for safety reasons.

1.15 Rescue operations and survival aspects

1.15.1 Alerting the rescue service

Several hours before the aircraft landed Finnair NCC informed the ATC of a hydraulic failure on the OH-LQE. On the basis of this information, the ATC was able to forewarn the rescue organisations in good time as well as reach a decision on procedures to be followed. Information of the tyre damage that occurred in Shanghai reached the ATC approximately 45 minutes before landing. During the final stage of the approach the captain of the aircraft informed the ATC of the effects the faults would have on the landing. Rescue units that were in readiness next to the landing runway were unaware of the tyre damage. Had they had this information, they would have positioned themselves differently.

In accordance with standing instructions, the ATC issued a formal alert at 11:22, approximately 30 minutes before landing. At this time, the various rescue service organisations received the alert. The ATC informed the flight crew of the raised level of preparedness. After the ATC pushed the emergency button, they provided detailed information to the Emergency Response Centre (ERC) by telephone as regards the type of aircraft, its problems, fuel quantity and number of passengers onboard as well as the runway to be used. The ERC, as per its own instructions, took care of the follow-on alerts.

Follow-on alerts and notifications were sent to numerous locations. The ERCs in the surrounding areas were informed of the situation. The ERC alerted medical response services by telephoning Töölö and Peijas hospitals.

1.15.2 Rescue preparedness

Already hours before landing, prior to the ATC's official emergency alert, the air traffic control, airport rescue services, Keski-Uusimaa Department for Rescue Services, emergency medical response services, the police and air ambulance Medi-Heli exchanged unofficial information. At the time they were only aware that there had been a hydraulic failure on the aircraft after its departure from Shanghai.

The air traffic control first alerted the airport rescue centre on-call fire officer (Lento P3). At approximately 08:30, as per instructions, Lento P3 called the on-call chief fire officer (KUP P3) at Keski-Uusimaa Department for Rescue Services and reported that the aircraft would be landing within approximately three hours. A detailed description of the exchange of information is included in Appendix 3. Since no precise diary was kept before the official alert was issued, some of the times are based on the recollection of the parties involved. KUP P3 continued to pass on the information and, at approximately 09:30, first called the Vantaa Police incident commander (K-1), followed by the chief medical officer (KUP L4) at Keski-Uusimaa Department for Rescue Services. KUP L4 then called the doctor of the air ambulance Medi-Heli and said that the aircraft would be arriving in approximately three hours. In addition, KUP L4 called the ambulance units that would probably be alerted to the site and informed them of the situation. KUP P3 also informed the on-call chief (KUP P2) at Keski-Uusimaa Department for Rescue Services as well as fire stations. The on-call chief and KUP P3 decided to set up an emergency operations centre so as to be ready for operations before the arrival of the aircraft. At 10:45 the emergency operations centre called and reported that they were ready and standing by.

At 11:13 KUP P3 notified the ERC of a possible emergency and directed them to follow standing instructions once they received the official alert.

The official alert was given at 11:22 when the ATC pushed the *full emergency* button. After the ATC confirmed this by calling the ERC, they raised response readiness to *full emergency – large* (*number of persons*).

1.15.3 Onboard emergency preparations

At 10:01 Finnair NCC reported to the flight crew the preliminary information that the pieces of tread found on the runway in Shanghai came from the OH-LQE. The flight crew did not know how extensive the damage was, or how the aircraft would handle during the landing roll. Therefore, at 11.12, the captain decided to prepare the cabin for an emergency. There was ample time to carry out the measures and they proceeded without problems. At 11:52, approximately two minutes before landing, the captain issued the command *Brace for impact*. After the aircraft came to a stop it was decided that there was no need to evacuate the aircraft and the captain gave permission to return to normal cabin procedures.

1.16 Tests and research

1.16.1 Retread separation

Figure 2. The damaged tyre

Due to a nail that was found in the tyre the damaged tyre was removed from OH-LQB on 14.9.2008. The tyre was retreaded at Bridgestone S.S. in Belgium. However, the re-treading company was not informed of the pinhole, nor was it detected during the in-spection. Prior to its removal the tyre had made 202 landings. After the retreading, the tyre was put on the OH-LQE on 11.3.2009. The tyre was again removed on 22.6.2009, at which time it had made 186 landings. Finnair's tyre repair shop says that, due to wear, an A340 tyre is replaced after approximately 400 landings.

Tyres do not have a limited number of landings. Instead, they are changed when their condition so warrants. Tyre pressures are measured during the A maintenance, every 800 flight hours. Other than that, tyre pressure is only monitored on the cockpit display, except after a tyre change.

During the flight to Shanghai the ACARS system did not transmit any fault reports related to hydraulics, tyres or brakes. On the return flight the tyre pressure indicators in the cockpit indicated normal pressure throughout the flight.

The Finnair brake and tyre repair shop inspected the damage to the tyre. The entire tread, broken to pieces, as well as sections of casing belt plies had detached. There is an aramid cord protector between the tread and the belt plies. The belt plies are made of nylon fibre. The largest piece of detached tread weighed 1.9 kg.

Figure 3. The detached tread and aramid fibre (white material)

The hole through which the tyre leaked was found on the casing, which had already been found and marked immediately after the landing. The investigation could not establish why the tyre did not deflate during the flight in spite of the hole. The tyre was put through a retention test. Due to safety constraints, the tyre was only pressurised to 3.85 bar. Results showed that the leak rate was fairly high. Within an hour, tyre pressure dropped to 3.41 bar and within the following 30 minutes to 3.31 bar. The nominal pressure of the tyre is 14 bar. Yet, the tyre did not deflate during the flight. Approximately one hour and twenty minutes after landing the cockpit instruments indicated 185 psi (12.7 bar) on tyre number 6. The other tyre pressure indications varied between 220 and

230 psi (15.2 and 15.8 bar). At that time some pressure had already been let off tyre number 6 to eliminate the risk of a blowout.

When the tyre was analysed a small pinhole was detected on the innerliner at the site of the leak. No other damage was found on the innerliner.

Figure 4 The FOD hole on the tyre as well as on the casing belt ply.

The venting channels on the rim were open and clean. The electric pressure sensor system adapter channels were open. The O-ring seal on the rim halves was intact and correctly installed. The thermal fuses (2) on the rim trip at 177 degrees. They had not tripped.

Random shapes of rubber material following a sporadic shear line had detached from the tyre. Rubber had separated directly off of the casing belt plies, i.e. much deeper than the undertread layer. A thin, smooth layer of rubber was found on the surface of the belt plies as well as visible signs of rubber flow. The belt ply nylon cord had broken off perpendicularly and cleanly along with the rubber material. When the detached rubber pieces were bent, deep fissures were detected. The piece of the belt ply that was picked up at the departure location showed a hole which corresponded to the hole found on the tyre casing (Fig. 4). The pieces of rubber collected at the departure site were dry and clean. Apart from the piece of tread on the landing gear axle, the pieces that separated during the landing at Helsinki-Vantaa were not collected.

Bridgestone S.A. (the retreading company) stated the following in its inspection and analysis report, dated 14.8.2009:

- Both external sidewalls were in normal condition;
- The tread had fully detached from the casing, varying at the interface between the 1st and 2nd belt plies;
- The FOD hole in the tyre could not readily be seen with the naked eye. However, it protruded into the complete casing ply section and perforated the innerliner;
- The hole was not present in the newly applied tread. Therefore, it was present in the tyre at the time of the last retreading process.

The report proposed that pressure began to gradually build up between the tyre tread and the casing through the hole. A small separation at the under-tread level continued to grow until the tread finally detached from the casing at takeoff in Shanghai. In static conditions the leak rate through the hole was low. However, it is likely that it greatly increased in dynamic conditions during taxiing, takeoffs and landings. Eventually, pressure began to build up between the tyre tread and casing, causing the tread to gradually detach. The retreading company considered this incidence a very isolated case.

1.16.2 Hydraulic system

Inspections revealed that both lines of the green hydraulic systems, fastened to the rear spar of the left wing in the wheel well, were damaged. The hydraulic lines are fully exposed in the wheel well. The lines in question alternate as supply and return lines, depending on the direction of travel of the landing gear. The upper (large) line shown in figure 7 is pressurised during landing gear extension and the lower (small) line is pressurised when the landing gear is retracted. Hydraulic pressure in the supply line is 3000 psi. Return line pressure is below 1450 psi. When the landing gear was retracted and all landing gear doors closed and locked, both hydraulic lines reverted to the return side. There was an approximately 10 mm long rupture on the lower line (Fig 7) and the line was leaking. The green system leaked at 3000 psi through the rupture until the landing gear doors closed.

There was a dent on the upper line (Fig. 7), next to the spot where the other line was ruptured, but it did not leak. When the system was tested, the dented spot sprang a leak at approximately 2200 psi. The line did not leak during the flight.

A leak on the spoiler system was detected during repairs. A T-union had not been sufficiently tightened. Every time the green hydraulic system was pressurised there was a leak. It is likely that this leak necessitated the following hydraulic fluid top-ups: three litres on 5.6.2009, two litres on 18.6., three litres on 19.6. and one litre on 20.6. Hydraulic fluid residue was detected on the left landing gear's shock strut on 17.6., 19.6. and 20.6. The union continued to slowly leak until the flight crew turned off the engine driven hydraulic pumps, i.e. 37 minutes after the takeoff. According to the aircraft manufacturer, the green system did not leak any more.

In the green system there are two check valves downstream of the reservoir which, according to the maintenance manual, ought to prevent the reservoir from emptying should

hydraulic lines be damaged. However, when asked, an Airbus hydraulic expert said that their primary function is to prevent pressure shock or the rapid emptying of the reservoir, for example, during maintenance. According to expert statement the aircraft's hydraulic system was operating normally. Airbus informed AIB Finland that they would amend the maintenance manual's verbiage as regards the check valves, so as to better explain their true function.

The brake line coupling on the left landing gear wheel number 2 was damaged. While braking is normally handled by the green system, due to the damage the system automatically assigned braking power to the blue alternate brake system. Normal pressure in the blue system is 3000 psi and the pressure in the alternate system with antiskid on is 2450 psi. However, the system only pressurises when the brakes are used. After the aircraft came to a stop the blue system continued to leak while engine number 2 was running because its hydraulic pump supplies the blue system. When the engines were shut down and the parking brake was on, the leak continued due to accumulator pressure. The accumulators emptied within approximately 2.5 minutes. Since the accumulators hold 6.2 litres, it can be calculated that fluid leaked at the rate of approximately 2.5 litres per minute through the damaged brake line coupling. There is one safety valve for each brake in the green system. The blue system has one safety valve for a pair of brakes sharing an axle. The safety valves are designed to automatically shut in less than five seconds if the brake system leaks at 25-27 litres per minute. This prevents the system from draining. The valve remains shut until the leak decreases to less than 10 litres per minute. If the system detects a leak at less than 10 litres per minute, the valve remains open. In this particular instance the leak was estimated at 2.5 litres per minute. Hence, the safety valve did not close.

Hydraulic fluid quantities are not registered in the flight data recorder system. This is why the investigation could not track the fluid level deficit in the green system. The aircraft manufacturer believes that, because of the leaks, the fluid level in the green system apparently decreased close to the low level caution, i.e. eight litres. As the flight continued the hydraulic fluid cooled down and decreased in volume until it reached and surpassed the low fluid level caution – eight litres. The low fluid level caution in the green system came at 4 hours and 22 minutes after takeoff.

Photos taken from the cockpit one hour and twenty minutes after landing indicate that the blue system was empty but the green system still contained approximately 2/3 of the normal fluid quantity. A part of this volume is return flow caused by the different systems, such as landing gear extension. Finnair Technical Services also consider it possible that the ruptured line sucked in air which caused the hydraulic fluid to froth, thereby increasing the volume detected by the measuring system.

1.17 Investigation methods used

Normal methods were used in the investigation. When it came to the inspection of tyre damage, the investigation commission relied on the inspection and analysis conducted by Bridgestone S.A., the retreading company, as well as Finnair.

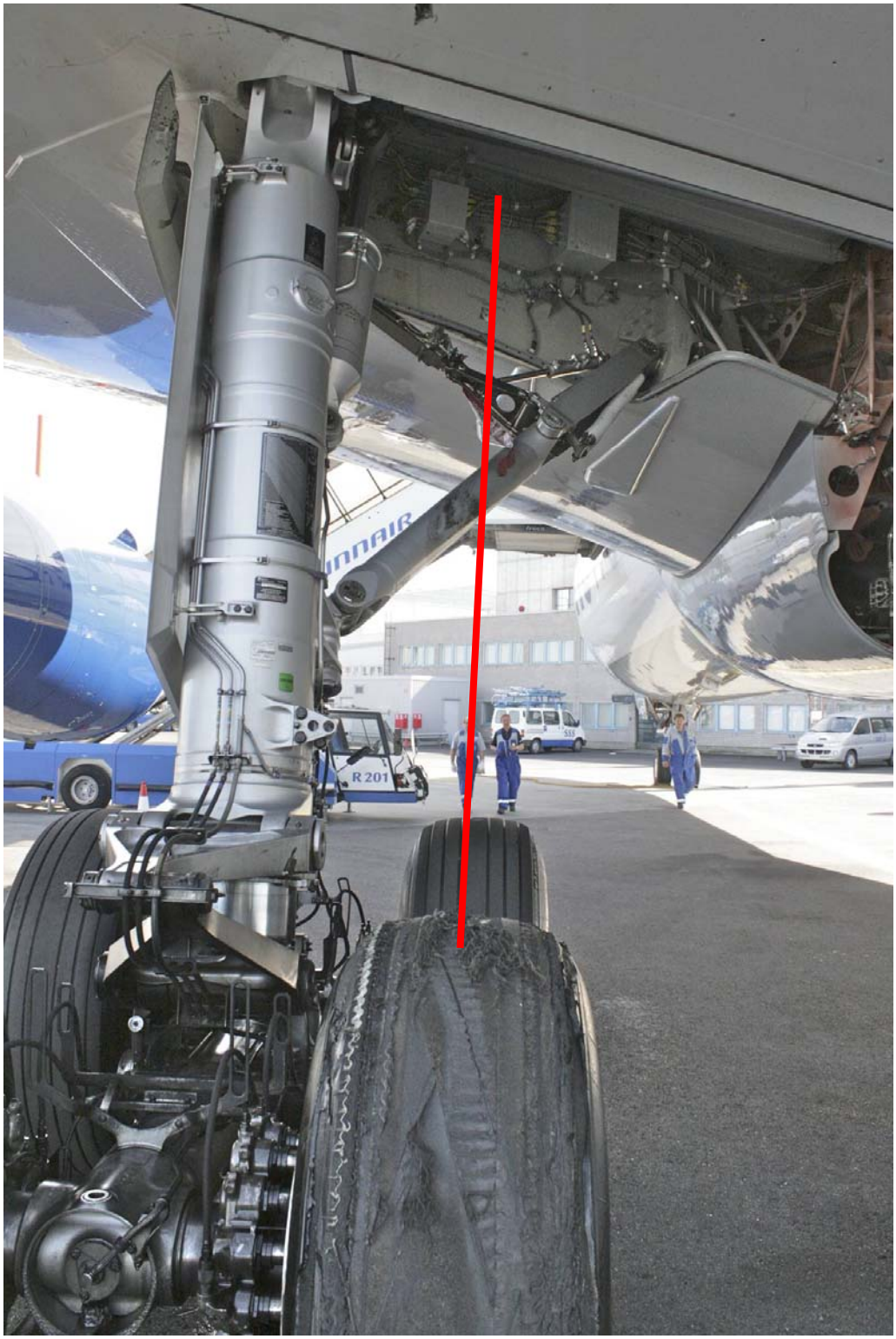


Figure 5. The detached tread's impact trajectory on hydraulic lines and electrical wiring shrouds

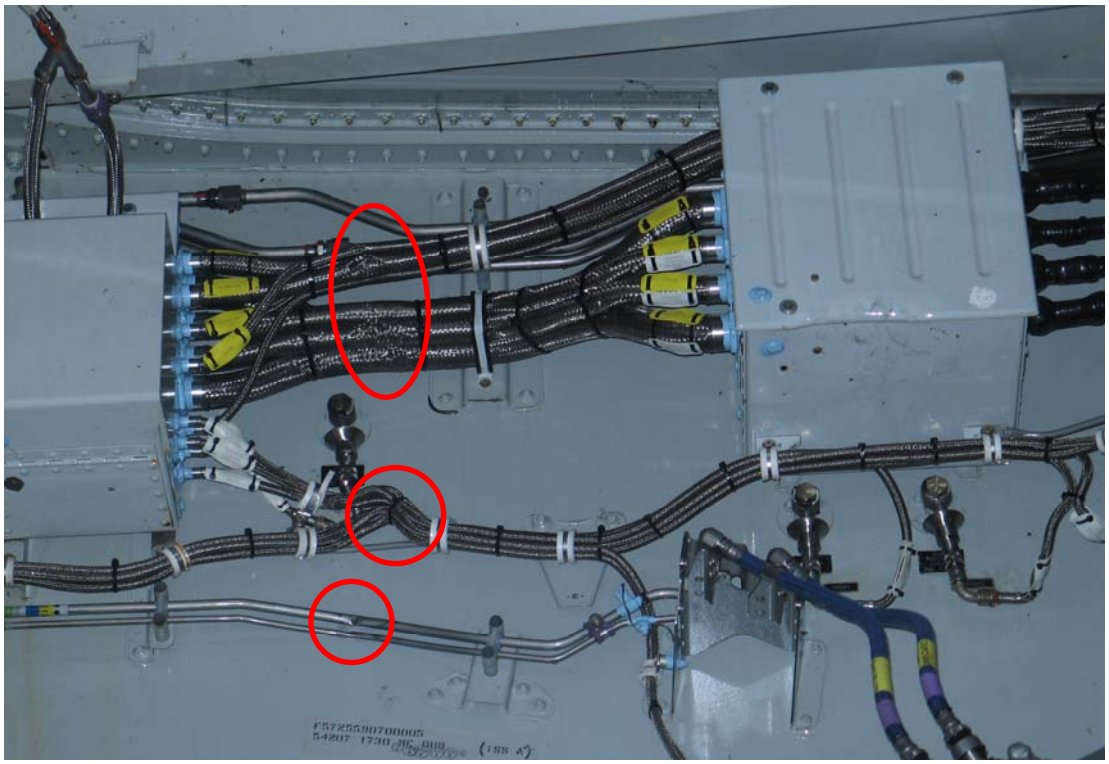


Figure 6. Damage to the hydraulic lines and electrical wiring shrouds in the wheel well

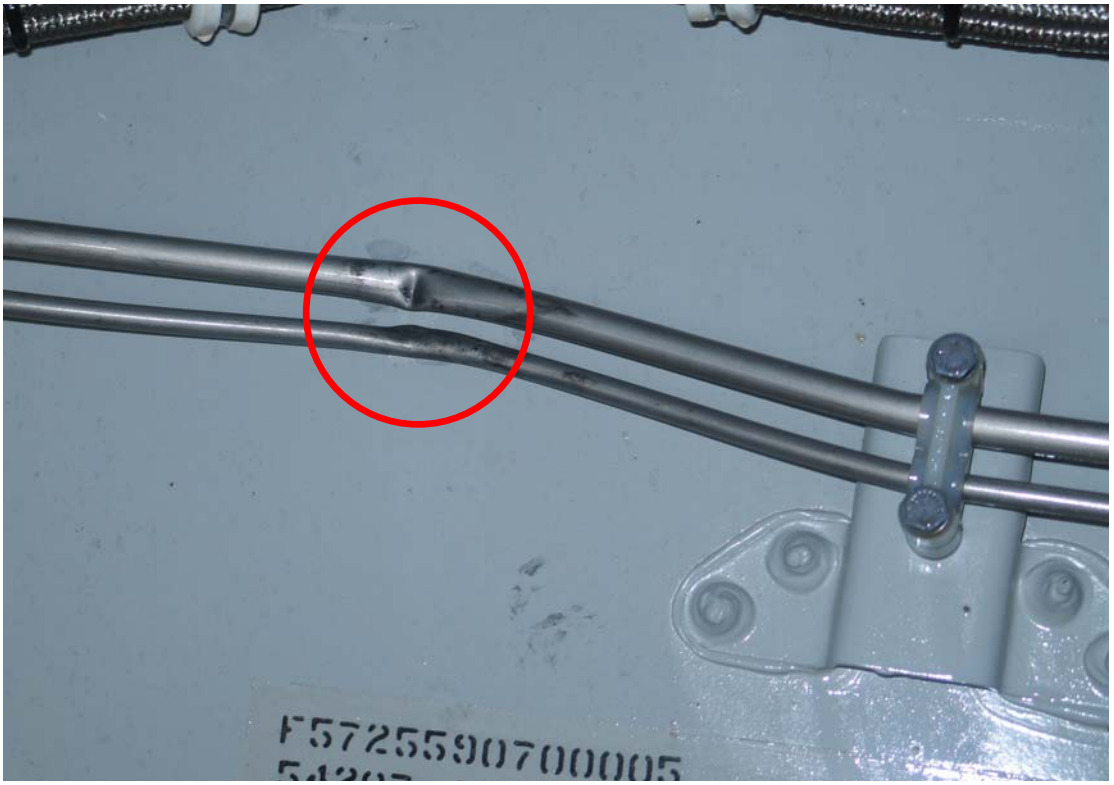


Figure 7. Damaged hydraulic lines

2 ANALYSIS

2.1 Tyre damage

The ACARS system did not relay any particularly noteworthy fault reports during the flight to Shanghai. On the return flight from Shanghai the tyre pressure indicators on the flight deck indicated normal ranges throughout the flight. Tyre pressures were not measured after landing. In order to prevent the risk of blowout after the landing, the damaged tyre was deflated to 185 psi (12.7 bar) as per the cockpit display. The tyre's nominal pressure is approximately 14 bar.

After takeoff, according to DFDR recordings, the wheelspin rate on wheel number 6 decreased faster than the other wheels. This was probably due to lower inertial forces caused by tyre delamination as well as the possible added friction of the pieces of rubber that were in the process of separating. DFDR data showed that wheel number 6 spun normally at landing.

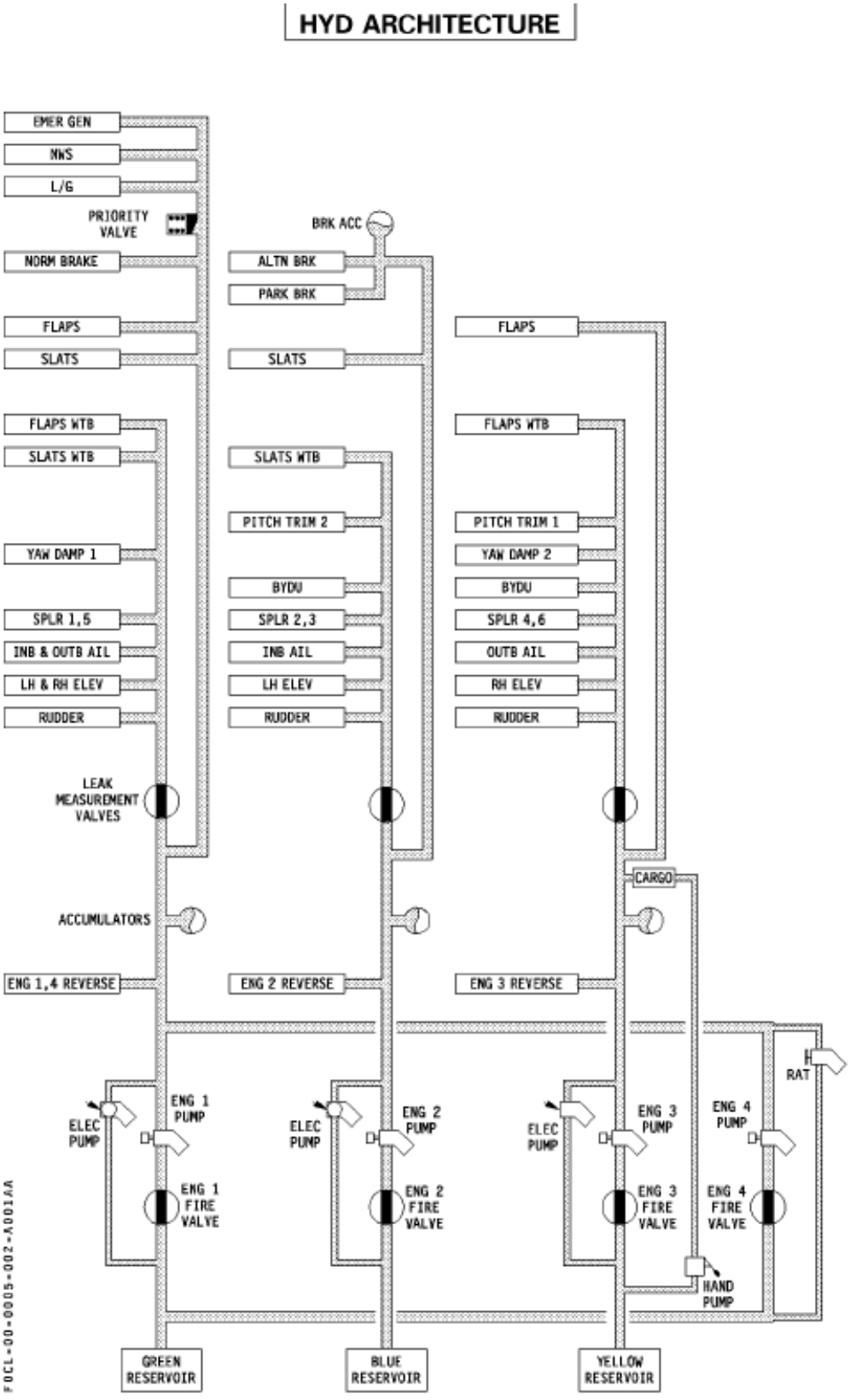
According to Finnair's tyre repair shop the tread displayed signs of rubber flow, which is an indication of thermal damage. No cause for the thermal damage was found. According to cockpit indications the tyre maintained correct pressure, the aircraft was not excessively heavy, nor did the DFDR data indicate abnormal taxiing speeds. The thermal damage was not caused by brake overheating. If this would have been the case, it would have first heated the rim from where the heat would have been conducted to the tyre. In any case, the rim's thermal fuses had not tripped which shows that the rim did not overheat. Nothing out of the ordinary was detected on the brake during damage repair.

Bridgestone's inspection and analysis report does not mention thermal damage. However, in subsequent correspondence it is stated that discoloration could be detected on the rubber surface, which indicates overheating caused by friction. Even though the pinhole on the tyre could not be detected with the naked eye, it perforated the entire casing and belt plies. There was no hole in the new retread, so it had remained beneath the retread. The report estimated that through the hole there had been a gradual build-up of pressure between the tyre tread and the casing, causing the tread to begin to separate and, finally, detach at takeoff in Shanghai.

The investigation commission believes that the tread separation was caused by a build-up of pressure between the tyre tread and the casing. The tread had gradually been detaching and then completely ripped off at takeoff in Shanghai. Rubber discoloration caused by overheating was detected during the inspection. It is possible that overheating degraded the integrity of the tread and the belt plies, accelerating the delamination.

2.2 Damage to the hydraulic system

The Airbus 340 has three hydraulic systems: green, blue and yellow. Each system has its own hydraulic reservoir, pumps and pressure accumulators. The pumps operate at 3000 psi (206 bar). The Hydraulic System Monitoring Unit oversees the systems.



Green Blue Yellow

Figure 8. Airbus A340 hydraulic systems (source: Airbus 340 AOM)

Pumps on engines 1 and 4 generate the hydraulic pressure for the green system. In addition, there is an electric pump which can be automatically or manually controlled. A pump driven by a ram air turbine (RAT) is the emergency system. The maximum fill level of the hydraulic reservoir is 38 litres. Among other things, the green system pressurises the landing gear system, nosewheel steering, brakes, flaps, leading edge slats, spoilers 1 and 5, yaw damper and the reverse thrust system on engines 1 and 4.

Hydraulic pressure for the blue system is provided by a pump on engine number 2 as well as a manually controlled electric pump. The maximum fill level of the reservoir is 29.5 litres. Among other things, the system pressurises the emergency brake system, parking brake, leading edge slats, flight controls, spoilers 2 and 3 as well as longitudinal trim and reverse thrust for engine 2.

The yellow system is driven by a pump on engine 3 as well as an automatically or manually controlled electric pump. The maximum fill level of the reservoir is 19 litres. Among other things, the system pressurises the flaps, longitudinal trim, yaw damper, spoilers 4 and 6, flight controls and reverse thrust for engine 3.

On the green system both return lines of the landing gear system are fastened to the left wing spar in the wheel well. The lines are not shielded and both lines were damaged. There was a 10 mm long rupture on the lower line of the left landing gear (Fig 7). When the landing gear is being retracted, the line carries the full 3000 psi (206 bar) pressure. The green system leaked through the rupture in the hydraulic line. There was a dent on the upper line which carried a return pressure of below 1450 psi. This line did not leak during the flight. When the system was tested it sprang a spot leak at approximately 2200 psi (155 bar).

When all landing gear doors are closed and locked the landing gear system only carries the basic pressure of 50-60 psi (3.5–4.2 bar) generated by engine bleed air. After this when the aircraft speed increases over 280 kts the landing gear hydraulic system is isolated from the aircraft hydraulic system. The isolation is cancelled when the speed reduces below 280 kts and the landing gear lever is moved to the down position. This means that there has been no leak through the damaged hydraulic line during cruise flight. There was some fluid left in the green tank during approach to Helsinki. When the crew initially tried to lower the landing gear hydraulically, no pressure was produced in the green system. Reason for this was not found out during the investigation. The hydraulic fluid reservoir that indicated a low fluid level during the flight had a higher fluid volume after the landing. This is because the fluid which was contained in the retraction actuators during landing gear extension as well as other systems eventually returned to the reservoir.

The investigation commission believes that the leak that was detected on the spoiler system during repairs was not a crucial factor with regard to the low fluid level in the reservoir. A slow leak through the spoiler's T-Union continued until the engine driven hydraulic pumps were turned off.

The brake line coupling on the left landing gear wheel number 2 was damaged. The investigation could not establish whether the damage occurred at takeoff or during landing. Braking is normally handled by the green system but, due to its damage, the system automatically assigned braking power to the blue alternate brake system. Normal pressure in the blue alternate brake system with antiskid on is 2450 psi (175 bar). The system only pressurises when brakes are being used. According to DFDR information, despite the leak in the blue system it retained normal pressure. Recordings indicate that brake pressure did not exceed 600 psi during braking, nor did the brakes pull to either side. After the aircraft came to a stop the leak continued because the parking brake was on. When the engines were turned off approximately two and a half minutes after the aircraft came to a stop, pressure in the blue system started to drop. At this time only the accumulators provided hydraulic pressure. They emptied within approximately 2.5 minutes at which time there was no pressure in the system and the parking brake became inoperative. The leak was so slow (approximately 2.5 litres per minute) that the safety valve did not close. The ACARS system did not provide information to Finnair Technical Services with regard to the fault in the blue system. This is because Post Flight Reporting (PFR) terminates when the speed of the aircraft decreases below 80 kt.

The photos that were taken approximately 1.5 hours after landing show that the brake temperature on wheel number two is consistent with the other brakes on the left landing gear. This indicates that, despite the leak, wheel number 2 decelerated in unison with the other wheels.

2.3 Functioning of other onboard systems

The aircraft's communications, monitoring and warning systems functioned as designed. Not only did the ACARS system report all faults to Helsinki, it also provided an efficient conference call link between the flight crew and Finnair NCC.

The monitoring and warning system ECAM generates cautions (amber) and warnings (red). On the cockpit displays both cautions and warnings show a diagram of the system in question as well as appropriate emergency procedures. If necessary, the flight crew can also consult the Quick Reference Handbook (QRH) and the AOM.

At takeoff cautions are normally not displayed until the aircraft reaches 1500 ft. During the landing phase cautions are blocked below the altitude of 800 ft and the speed of 80 kt. This makes it possible for the crew to focus on the critical phases of the flight.

During the takeoff an amber caution BRAKES HOT was displayed in the cockpit. The caution came from the second rear brake on the left main gear. When airborne, the brake temperature on wheel number 5 was 290 degrees, but the brake on wheel number 6 was also hot. According to the AOM it is not permitted to commence a takeoff if the ECAM displays the BRAKES HOT caution. However, it is not grounds for an aborted takeoff. As per DFDR data, the brakes heated because left braking was used more intensely than right braking during taxiing.

The ECAM displayed all hydraulic leak indications which were also relayed to Helsinki.

2.4 Crew action

Crew action was assessed on the basis of interviews with the flight crew and the chief of cabin. Also ACARS messages, DFDR and CVR data as well as ATC recordings were used to augment the overall picture.

The captain was the Pilot Flying (PF). The co-pilot was the Pilot Not Flying (PNF). There was also a captain-rated relief pilot (Second in Command) onboard who acted as the pilot during breaks.

Pre-flight briefing proceeded normally and nothing out of the ordinary was detected during the external inspection. Taxiing from the stand to the takeoff runway took 15 minutes and, due to traffic, the aircraft was stopped several times. On straight taxiing sections the maximum speed reached 30 kt and in turns 8 kt. These were within AOM limits. The left brakes were used more intensely compared to the right brakes and this caused the BRAKES HOT caution during takeoff. Takeoff was not aborted because the AOM does not call for an abort. Because of the caution, the landing gear was left down longer than normal so as to cool the hot brakes.

As regards the hydraulic system cautions, the pilots acted in accordance with ECAM instructions. They also consulted the QRH (which, along with other things, contains check lists) regarding the consequences of the loss of the green system. Finnair Technical Services and the flight crew used the ACARS to exchange information. At this time it became evident that, among other things, hydraulic fluid had been frequently added to the green system during the past two weeks. This supported the crew's notion that the draining of the reservoir on this flight was caused by a prolonged leak at an unknown location.

The captain informed the chief of cabin (CC) of the hydraulic fault and added that, for the time being, it would not require any particular action in the cabin. This information was also given to the cabin attendant in charge of the rear cabin. When the information regarding the tyre damage reached the crew, nothing indicated a relationship between it and the hydraulic fault. They did not know how extensive the damage to the landing gear and in the wheel well was. Since it was uncertain how the aircraft would handle at landing, the captain ordered the cabin crew to prepare the cabin for an emergency.

While the flight crew actively communicated with the NCC, they did not make certain that the ATC was informed of the extent of the damage, or of the preparations in the cabin. The ATC informed the pilots of the raised readiness at the airport.

The entire crew worked well together and all procedures were implemented as per instructions.

2.5 Air Traffic Control and aerodrome maintenance action

Because cooperation between Helsinki-Vantaa air traffic control and Finnair NCC worked well, the ATC was informed early on regarding the expected emergency situa-

tion and, therefore, was able to properly prepare for it. Runway 22L was exclusively reserved for the OH-LQE, which was able to approach without delay. The risk of an unforeseen situation arose when information regarding the tyre damage as well as the fact that the aircraft could not vacate the runway on its own arrived relatively late in the situation. This would entail closing runway 22L until further notice and taxiway Z for the time it took to tow the aircraft. This would have also impeded taxiing to other runways. It looked like runway 22R was the only option. This would have caused delays to arriving traffic. After a quick assessment of the situation, however, it was realised that the radar controllers were able to reroute the arriving aircraft to land on runway 15. This meant that runway 22R could be used for takeoffs. The critical point would be to clear the intersection of runways 22L and 15 of debris that would possibly come off of the OH-LQE. Airport maintenance prepared for this by earmarking three runway sweepers for this task. These arrangements were sufficient to guarantee the flow of traffic at the airport without undue delays. At the same time the ATC could forewarn the other authorities at the airport as well as emergency response services.

2.6 Rescue service and survival aspects

Information regarding the hydraulic fault and the possible emergency was available several hours before the OH-LQE landed. This made it possible to alert the rescue services early on. Preparations were launched by providing the response units with information on the potentially required rescue activities. It was possible to estimate the required level of emergency response in advance. Emergency operations centres were set up an hour before the aircraft landed. Still, precise information as to the tyre damage only reached the ATC and the rescue services 13 minutes before landing. When the aircraft landed the entire rescue organisation, as per the required emergency response, was ready and standing by in pre-planned positions. When the aircraft came to a halt, they regrouped so as to be ready for an eventual fire or evacuation. But since the aircraft stayed on the runway, no additional damage ensued and there was no need to evacuate the passengers. Rescue was not needed. The only risk factor involved the spray of hydraulic fluid vaporising off of the hot brakes onto the left landing gear. A risk of fire was present. The fire fighters cooled the brakes, which ended the vaporisation. Then, the fire units absorbed the hydraulic fluid off the runway. The rescue services worked well and followed the aerodrome emergency plan.

Approximately 40 minutes before landing the captain decided to prepare the cabin for an emergency. The cabin crew did this in accordance with their instructions and no panic ensued. The passengers had to assume the brace position for approximately three minutes. The captain’s decision was appropriate because the flight crew was unaware of the extent of the damage, or how the aircraft would handle during the landing roll. The ATC, however, was not informed of these preparations.

During the course of the investigation the commission was contacted because it was felt that hospitals had not been informed of the emergency early enough. Hospitals had half an hour to prepare for possibly receiving a large number of patients. This is, admittedly, a short time to raise medical response readiness. According to information submitted to the investigation commission, it is the duty of the ERC to alert hospitals. The official alert

was issued approximately 30 minutes before the aircraft landed; hospitals received the alert six minutes after it was given. As per ERC regulations hospitals should only be alerted following an official alert. The parties involved should get together and come to an agreement regarding possible changes to the regulations.

2.7 Incident classification

ICAO Annex 13 defines events which are classified as serious incidents, such as multiple malfunctions of one or more aircraft systems seriously affecting the operation of the aircraft. The EU Council Directive 94/56/EC contains a corresponding list of serious incidents.

In this incident the tyre tread on the aircraft's left landing gear detached at takeoff, causing pieces of rubber to impact the wheel well and other structures at high velocity. Hydraulic lines in the wheel well sustained a rupture and a dent. The brake line coupling on wheel number 2 was damaged. Even though a trailing edge flap sustained a tear, it did not hamper the functioning of the flap. There were also impact marks elsewhere on the aircraft.

The green hydraulic system drained below the minimum fluid level. This caused the following faults:

- Landing gear had to be extended by gravity extension; in such a case the center gear does not extend;
- Nosewheel steering was inoperative;
- Reverse thrust on engines number 1 and 4 was unavailable;
- One pair of spoilers was inoperative, lengthening the landing roll by approximately 15%; and
- The alternate braking system became operative.

The brake system automatically uses the blue system as an alternate system. Since a brake line coupling on wheel number 2 was broken the blue system drained after the aircraft came to a stop. The brake pressure accumulators also became depressurised, rendering the blue system inoperative. The aircraft stopped on the runway with the passengers still onboard. The investigation commission considers the situation to be failure, during the same flight, of two hydraulic systems seriously affecting the operation of the aircraft.

The remains of retread found on the runway in Shanghai came from tyre number 6. The tyre pressure display in the cockpit indicated normal pressure. The flight crew had no means to find out whether any other tyres were damaged or whether the damaged tyre would hold up during landing. They were uncertain as regards the handling of the aircraft at landing. Therefore, the captain's decision to prepare the cabin for an emergency was appropriate and reasonable.

The investigation commission considers this occurrence to be a serious incident.

3 CONCLUSIONS

3.1 Findings

1. The certificate of registration and the airworthiness certificate were valid.

2. The flight crew had valid licences and the required ratings.

3. Visual Meteorological Conditions (VMC) prevailed at takeoff and landing.

4. The flight was a scheduled passenger flight.

5. During the final stages of takeoff the tread of tyre number 6, the rear tyre on the left main landing gear, separated and pieces of rubber impacted with aircraft structures at high velocity.

6. Remains of retread were found at the point of departure and the matter was reported to Finnair.

7. On the basis of photographs, Finnair Technical Services identified the tyre as belonging to the OH-LQE and reported the fact to the flight crew.

8. In the wheel well, pieces of rubber damaged the landing gear hydraulic lines, the brake line coupling of wheel number 2 and electrical wiring shrouds. They also damaged a flap and caused other minor damage.

9. The green hydraulic system depleted below the minimum fluid level during the flight.

10. The Aircraft Communication Addressing and Reporting System (ACARS) reported the faults to Finnair Technical Services in Helsinki.

11. The Electronic Centralized Aircraft Monitor (ECAM) warned the flight crew of the hydraulic fault.

12. The flight crew implemented corrective action as per ECAM instructions, discussed the situation with the technical services via ACARS and prepared for landing by taking the consequences of tyre damage and a hydraulic failure into consideration.

13. Finnair Network Control Center (NCC) informed the air traffic control of the expected emergency situation.

14. The ATC issued a preliminary alert to the Airport Rescue Centre which, in turn, relayed the information to Keski-Uusimaa Department for Rescue Services and the Police.

15. Approximately 30 minutes before landing, the readiness condition *full emergency – large* entered into force. The airport also raised response readiness and implemented other alerts i.a.w. standing instructions.

16. Approximately 40 minutes before landing the captain ordered that the cabin be prepared for an emergency.

17. The landing was successful. After the landing the blue hydraulic system drained empty through a damaged brake line coupling.

18. Because nosewheel steering was not available, the aircraft could not vacate the runway. It was towed to apron where the passengers were able to deplane.

19. The crew of the aircraft was debriefed twice after the occurrence.

20. Pursuant to ICAO Annex 13 classification, the occurrence was a serious incident.

3.2 Probable cause

The damaged tyre had previously been on another aircraft. It had been removed and sent for retreading because a hole was discovered in it. The pinhole was not reported to the retreading company, nor was it detected during the process. After retreading, the tyre was put on the OH-LQE. Thereafter, through the pinhole a gradual build-up of pressure between the tyre tread and the casing caused tread separation that resulted in complete delamination at takeoff in Shanghai. Rubber discoloration caused by overheating was detected during the inspection. It is possible that overheating degraded the integrity of the tread and the belt plies, accelerating delamination.

The leaks on the green and blue hydraulic systems were caused by the tyre shreds' impact energy when they hit the hydraulic lines in the wheel well as well as the brake line coupling on wheel number 2.

4 SAFETY RECOMMENDATIONS

4.1 Measures implemented

1. During the investigation Airbus informed the investigation commission that they would amend the maintenance manual's verbiage as regards hydraulic system check valves, so as to better explain their true function. The amendment was published on 1 April 2010.

2. Finnair has changed its instructions on fault inspection and damage reporting procedures as regards tyres sent for retreading.

4.2 Safety recommendations

Justification: The investigation revealed that the hydraulic fault was caused by high-energy rubber pieces impacting the fully exposed hydraulic lines in the wheel well. The rubber pieces also damaged electrical wiring shrouds.

1. The investigation commission recommends that Airbus Industries evaluate the need and possibilities of shielding hydraulic and electric systems in wheel wells.

Helsinki 27.4.2010

Vesa Kokkonen

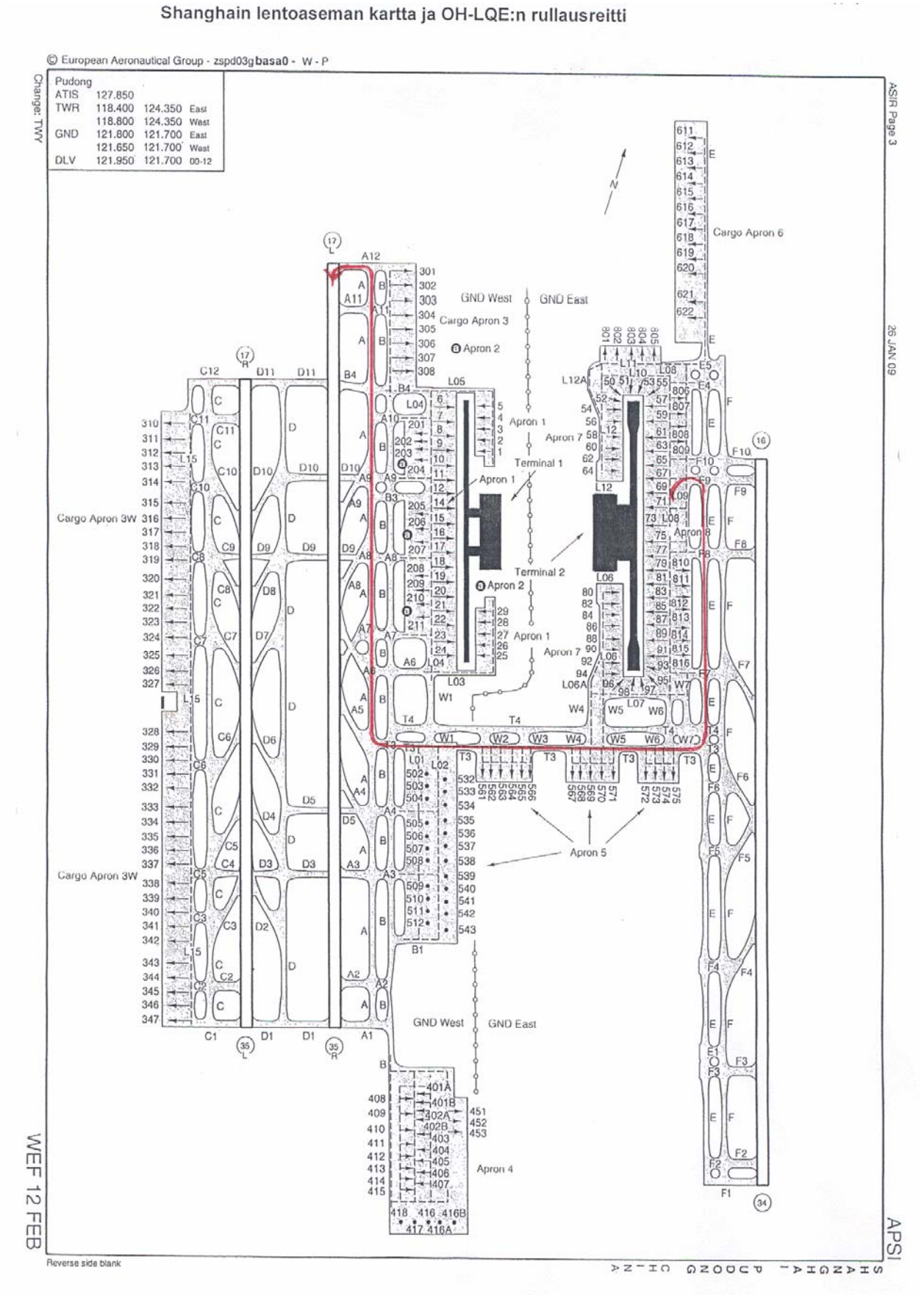
Jouko Koskimies

Niina Aintila

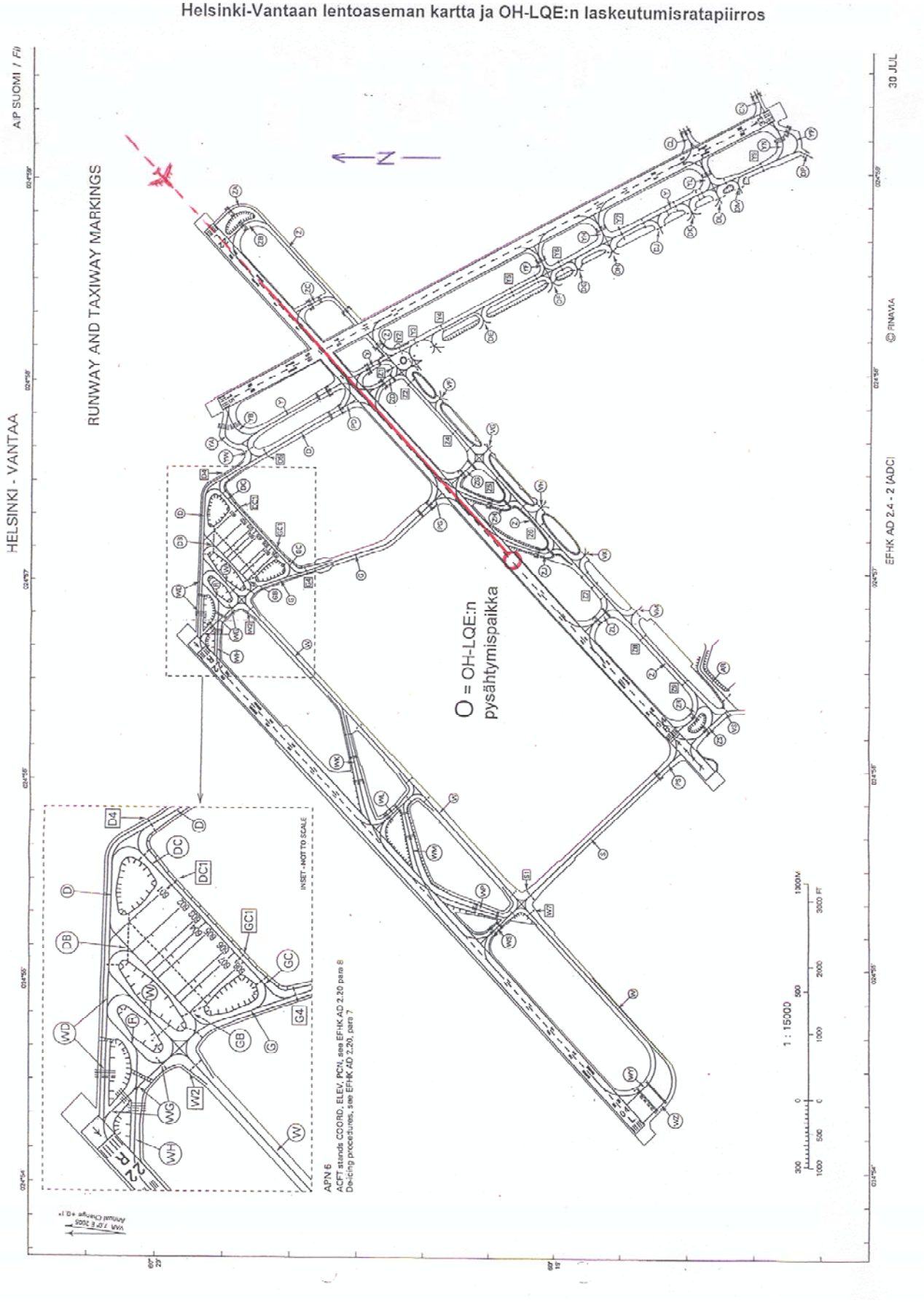
Heikki Harri

Appendix 1

Shanghain lentoaseman kartta ja OH-LQE:n rullausreitti



Shanghai aerodrome chart and taxiing route of the OH-LQE
Source: European Aeronautical Group



Helsinki aerodrome chart as well as the landing track of the OH-LQE

Source: AIP Finland